Prospectors' GUIDE

For MANITOBA AND NORTH-WEST ONTARIO

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when the agony is at its worst, bursts the Help with force
some into.

1938 Edition

Practical Geology and Mineralogy for Prospectors

P3

The Formation and Occurrence of Mineral Veins

With Particular Reference to the Northwestern Fields

By CHRISTOPHER RILEY

IN ORDER to secure a better background for an understanding of the formation of mineral deposits, it will be well to go back to the sort of beginning most pre-Cambrian deposits must have had. During its very long history, the earth's crust has undergone many periods of readjustment. It is widely believed that this has been due to a compacting of the earth's interior, and the crust, in adjusting itself, has wrinkled much as the skin of an apple does when its interior becomes smaller due to a loss of moisture.

The crustal folding, which, by the way, results in the building of mountain systems, releases pressure at great depths. The rocks at these depths are highly heated, and are only solid because the pressures have kept them so, and with release they become molten. The resulting melt, or magma as it is called, is very complex in its composition since rocks are made up of very many different substances. The most important of these substances, from our point of view here, are the metals and the mineralizers.

Metals are found disseminated in small amounts in all rocks though some are found in larger amounts in certain types, as nickel in the basic rocks. The mineralizers are substances, which, under high temperatures, become gaseous. The most important of these is water.

The magma is always under what, at the surface, wouid be terrific pressure, even though less than when the rock was solid. No great open spaces appear therefore, when the folding of the crust occurs. The magma forces itself into these as fast as they are formed. This process is called intrusion. It is too complex to be fully described here but it will be clear that the magma will also be forced in all smaller open spaces such as cracks and into all planes of weakness not great enough to resist the magmatic pressure. No doubt the magma does a certain amount of stopping with an assimilation of the intruded rock.

After the crustal movements are pretty well over, the magma begins to solidify. At great depths the cooling is slow and there is time for the growth of large crystals. The resulting rocks are coarse-grained and are granites, syenites, diorites, gabbros and so forth, according to the composition of the magma. Nearer the surface, where the cooking is quicker, the fine grained granites, syenites, etc., the porphyries, and the other diked rocks are formed. A magma reaching the surface become a volcanic rock. Here are found the rhyolites, trachytes, andesites, basalts and so forth.

Mineral deposits originate mostly from those rocks cooling at considerable depth. It is generally believed that, sometimes after crystallization begins, the mineralizers percolate through the magma and take the metals into solution and carry them upwards.

During the main period of folding and for sometime afterwards, there is a good deal of fracturing of the rocks. Some of the magma is forced into the fractures, and, cooling there, makes dikes and sills of porphyry. The liquors, carrying the metals and other vein-forming

matter, find their way also into fractures and there form veins. Not all of these carry the metals in large enough quantity to mine, in fact, only a minority of them carry ore.

It can be seen from this why it is that the porphyries and ore deposits are so often found together, since both originated from some great magma below. Sometimes, however, the ore solutions have their origin in the porphyry magma rather than in the main magma. In such cases they are found surrounding, and above, bodies of porphyry.

The rocks overlying the magma usually consist of sediments or volcanics which may or may not have been made into schists during the intrusion. The folding has made mountains from these rocks, and, during the long ages since, they have been so largely worn away that the underlying granite has been exposed. This has proceeded so far in the pre-Cambrian that it is about seventy-five per cent granite, and the older rocks remain only as remnants, like islands in a sea of granite. These islands are the favorable prospecting areas. As a point of interest it may be added that, in the pre-Cambrian areas, there have been at least two periods of mountain building with intervals of deep erosion between.

The chief structural features produced in the folded rocks are upfolds or anticlines and down folds or synclines. It is worth remembering that, while most of the metals seem to have no preference for any particular structure, gold favors the synclines. Furthermore, the favored position in them is around the edges of small dome-like intrusions which have pushed up into the synclines. Another good prospecting area is on the margins of the islands, that is, at the contact of the older rocks with the granite. Sometimes veins are found within the granite for distances up to one mile from the contact. Workable deposits are rare here. The term granite is used here to represent all the coarse rocks such as diorite, synite, etc., which might be mineral bringers, because granite is the most commonly found type in the pre-Cambrian.

From this discussion, a few general rules for prospecting the pre-Cambrian can be made. The prospector should select one or more of the favorable areas for his season's work. These are mapped in many districts by the government geological surveys and the maps and reports are of great assistance. He might, in a little prospected region, cover ground rather quickly and, in this reconnaissance, select those localities showing porphyry dikes and signs of mineralization. Here his work should be very painstaking as good deposits might easily be overlooked. Rusty places, called gossans, which are formed by the weathering of iron sulphides, are good indicators.

A gold pan, mortar and pestle are indispensible, and should be in constant use in prospecting for gold. This metal occurs most often with sulphides, in invisible form. Where the sulphides have weathered, the gold is released and may be panned directly from fresh sulphides by burning a piece in the fire and then crushing and panning. If there are no results in the first panning, the roasting and crushing should

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The Study of Minerals and Rocks

Minerals and rocks are determined or identified by the observation of their properties.

MINERALS

For minerals these are especially Lustre, Colour, Colour of Powder (also called "streak"), Hardness, Crystal Form, Cleavage, and Specific Gravity, or weight as compared with other substances. These properties have already been studied. Some of them are useful in all minerals; others are limited to a section or are only useful in occasional cases.

All minerals can be studied as to their Lustre, whether Metallic or Non-Metallic. Our table is, therefore, divided into two main divisions, the first containing minerals of metallic lustre, the second those which are non-metallic in appearance. Some are of doubtful character, or are in some cases metallic and in other cases non-metallic. These will be found in both sections of the table.

The first thing to do, therefore, when we wish to find out the name of a mineral is to study the specimen for the purpose of deciding whether its appearance is metallic or non-metallic. For practical results one must only ask himself the question, "Does this mineral appear like a piece of metal or like glass, stone, earth, resin, wax, or some other non-metallic substance?" If some difficulty is still felt, we recall that metals are always of a more or less shiny or polished surface and that they also have the appearance of a hard surface, the exact position of which is distinctly seen because they allow no light to pass through even in very thin sheets. Being also good conductors of heat they are cold to the touch unless heated above the body temperature (98° F.). The non-metallic substances, on the other hand, while they may or may not have a polished surface, which reflects light, have in general a softer or less distinctly seen surface, especially if one holds them at right angles to the eye, because they are more or less translucent or even transparent. Looking straight down into a quiet pool of clear water, for example, one is sometimes not sure just where the surface is, but looking at the polished surface of a piece of steel or silver, one has no doubt as to its exact position. All dull or lustreless surfaces, also, are non-metallic even if opaque.

Having decided on the first point, we can now neglect that part of the table which does not contain minerals of the observed type of lustre and confine our attention to the part which includes those of the right lustre.

MINERALS OF A METALLIC LUSTRE

COLOUR

If we have decided that the lustre of our specimen is metallic, the next point is that of the colour, Colour is generally very uniform in metallic minerals, and therefore they are easily recognized by their colours. The colour of the powder is also characteristic in many cases, and often valuable when considered along with the colour of the crystal or massive form. The tables recognize five distinct metallic colours: (1) yellow, (2) red or reddish, (3) white, (4) grey, (5) black. There are also blue or bluish colours, but they are not commonly enough found to require a place in this table. As an example the blue and green tarnishes in copper ores might be mentioned. In the

massive state, however, these substances, azurite and malachite, are distinctly non-metallic in appearance.

Under the heading of Metallic Lustre, therefore, the first subheading is that of Colour. Having observed the colour of our specimen, we turn to the section Yellow, Red, Grey, White, or Black, to which it belongs.

HARDNESS

The minerals of each colour are next divided into two groups according to their hardness, which is tested by scratching with the point of a knife on a clear fractured surface or flat crystal face. If the knife is harder than the mineral it will make a mark (a small groove) in the mineral without more pressure than can be easily applied by a slight effort of the thumb. If the specimen consists of very fine crystals or grains they may be loosely attached to each other and will merely come apart on scratching. This in not a correct test of the hardness of the grains. An alternate way in such cases is to try scratching the blade of the knife with the mineral. If harder it will scratch the steel visibly without too much pressure. Other tests of hardness easily used are the finger-nail for soft minerals, and a piece of quartz for very hard ones. A scale of hardness of 10 degrees has been devised by Mohs. Those scratched by the knife have a degree of hardness from 1 to 5; those not scratched are from 6 to 10. This scale makes use of the following 10 minerals:—

1. Talc (very soft).
2. Gypsum (finger-nail, about 2¼).
3. Calcite (copper cent, a little harder than 3).
4. Fluorite.
5. Apatite (knife blade, about 5).
6. Feldspar.
7. Quartz.
8. Topaz.
9. Corundum.
10. Diamond (the hardest mineral known).

OTHER PROPERTIES

After hardness has been tested and the proper place in the table found under that heading, we find that there are several minerals grouped together under this head which are separately described, each by its own properties, as to exact colour, crystal form, cleavage, tarnish due to weather, or other individual peculiarities. Beginning at the first we compare our specimen with these descriptions until we reach the one which fits it most nearly. We should then refer to the name on the right side of the page, which is the correct name of our specimen if we have followed it correctly. In order to make sure of this, it is advisable, especially at first, to begin at the beginning of the table and follow through, passing over each heading that does not fit the specimen, and going through from the beginning each part of the table that agrees with it in the same way. After a little practice the table can be used much more rapildy without making mistakes. The table has the double advantage of finding the name of an unknown mineral, and of teaching one to observe correctly and quickly the various properties of minerals, and thus to become better acquainted with them.

MINERALS OF A NON-METALLIC LUSTRE

COLOUR

In the non-metallic minerals colour is often due to the staining of the mineral by some coloured matter, mainly metallic oxides, which are present in extremely small amounts, so that while a large piece of the mineral appears coloured, the powder is always white. This is especially true of the transparent or translucent minerals. Some non-metallic minerals, however, have definite colours of their own, and also a definite colour of powder, which may or may not be the same as that of the crystal.

COLOUR OF POWDER

It is, therefore, better to divide the non-metallic minerals according to the colour of their powders rather than of their crystals. They are first divided into two groups: (a) Those having definitely coloured powder, to which belong most of the opaque minerals of this class; and (b) that group whose powders are either white or of pale neutral colours.

The first group is then divided under the different colours of powder. Minerals whose powder is of the same colour are distinguished by other features, such as cleavage, hardness, weight, colour, and form of the crystal. Minerals that produce a powder of a white or faintly coloured shade are next divided into two classes according to their hardness.

HARDNESS

Hard to Scratch by Knife or Not Scratched (6-10)

These cannot be scratched with a knife or not without using considerable force. In most cases, if we try scratching the knife with the minerals, we get a good proof that it is harder than the knife, and therefore above 5 in the scale of hardness. If the hardness is above 5, the minerals are next examined as to cleavage.

Cleavage.—As stated elsewhere, cleavage is the property of parting with a flat smooth face when broken. In all crystals, there is a regular arrangement of the particles or molecules, which extends through the crystal and is due to the way in which the particles have attached themselves together during the growth of the crystal—much as bricks are laid in courses. Some crystals are so constructed that they break most easily along a plane between two such courses. These are said to have cleavage. Others break irregularly across the courses or in curves (conchoidal fracture). These have no cleavage. Some substances are not crystallized, and in these, of course, there is no cleavage. Any break other than a true cleavage is called a fracture.

In the hard minerals (above 5) some are included which have no cleavage. They are distinguished by colour, crystal form, and type of fracture, and include quartz, tourmaline, and garnet. Of the hard minerals that have a cleavage, we have (a) a light-coloured group (feldspar and corundum), which are easily distinguished by their difference in hardness, as well as by the angles between their cleavage faces and the shape of the crystals when the whole ones can be seen; (b) a darker-coloured group with less perfect cleavage (hornblende

and pyroxene); (c) a group distinguished by shades of colour and difference in crystallization (epidote and olivine).

Scratched by Knife (1-5)

Of the non-metallic minerals that have a pale powder and can be easily scratched by the knife, there are a number of carbonates that have a similar cleavage (rhombohedral) but differ in hardness, specific gravity, and reaction with hot or cold, acid. There are also fluorides, phosphates, sulphates, and silicates containing water produced by the chemical action of the rain on other silicates. In separating these, use has been made of their relative weights, or specific gravity. In small specimens, it is not easy to distinguish this property accurately merely by the pressure felt when holding them in the hand. If it is desired to make a fairly accurate determination of specific gravity, this can be done by the use of an ordinary scale or spring-balance used for weighing letters. A small piece of the pure mineral is attached to the pan or hook of the balance by a fine piece of thread and weighed. It is then weighed again while holding a cup or glass of water underneath in such a way that the mineral is completely under the surface of the water while being weighed. It will be found to weigh less than in the air. The difference in weight is due to the buoyancy of the water and amounts to the weight of a volume of water of the same size as the mineral specimen. We then divide the weight of the specimen in air by the difference between the two weights, which equals the buoyancy or weight of an equal volume of water, and the result is the specific gravity of the mineral, that is, the number of times heavier a unit volume (say a cubic inch) of the mineral is than an equal volume of water. This number is expressed by "G," which stands for "gravity." For example, "$G=3$," if we find our mineral specimen to weigh 6 ounces in air and 4 ounces under water, since the difference between 6 and 4 is 2, and $6 \div 2 = 3$. The mineral is therefore three times as heavy as water, and the gravity of water is taken as the unit of measurement.

CHEMICAL COMPOSITION OF MINERALS

Minerals are substances which are formed by the process of nature and which do not belong to the vegetable or animal kingdoms. They are composed of simple substances called elements. Some minerals consists of only one element. They are then known as *native* elements, such as graphite (native carbon), native gold, and native silver.

Other minerals are composed of more than one element, combined together in what is called a chemical compound. Examples of these are:—

The *sulphides* which consist of a metallic element combined with sulphur, such as pyrite (iron + sulphur).

The *oxides,* such as quartz (silicon+oxygen).

These are simple compounds, consisting of only two elements combined. Others are more complex and are formed by the combination of two or more simple compounds.

Each individual element is made up of atoms (very small particles) which are alike and especially so in their weight. The lightest atoms are those of hydrogen. Their weight is used as a unit to measure the others. An iron atom for example weighs roughly 56 times as much as one of hydrogen, and one of oxygen 16 times as much. These numbers are called the atomic weights of the elements. Short forms or single letters are used instead of writing out the full name of an element,

and are combined when describing compounds—FeS_2, for example, is the symbol for Iron Pyrites. It means that each molecule of iron pyrites contains one atom of iron (Fe) and two atoms of sulphur (S).

The following table contains a list of the common elements with their symbls and atomic weights:—

LIST OF ELEMENTS, THEIR SYMBOLS AND ATOMIC WEIGHTS

Element	Symbol	Atomic Weight	Element	Symbol	Atomic Weight
Aluminium	Al	26.97	Mercury	Hg	200.61
Antimony	Sb	121.76	Molybdenum	Mo	96
Argon	A	39.944	Neodymium	Nd	144.27
Arsenic	As	74.93	Neon	Ne	20.183
Barium	Ba	137.36	Nickel	Ni	58.69
Beryllium or			Nitrogen	N	14.008
Glucinum	Be	9.02	Osmium	Os	190.8
Bismuth	Bi	209	Oxygen	O	16
Boron	B	10.82	Palladium	Pd	106.7
Bromine	Br	79.916	Phosphorus	P	31.02
Cadmium	Cd	112.41	Platinum	Pt	195.23
Caesium	Cs	132.81	Potassium	K	39.1
Calcium	Ca	40.08	Praseodymium	Pr	140.92
Carbon	C	12	Radium	Ra	225.97
Cerium	Ce	140.13	Radon	Rn	222
Chlorine	Cl	35.457	Rhodium	Rh	102.91
Chromium	Cr	52.01	Rubidium	Rb	85.44
Cobolt	Co	58.94	Ruthenium	Ru	101.7
Columbium	Cb	93.3	Samarium	Sa	150.43
Copper	Cu	63.57	Scandium	Sc	45.1
Dysprosium	Dy	162.46	Selenium	Se	79.2
Erbium	Er	167.64	Silicon	Se	28.06
Europium	Eu	152	Silver	Ag	107.88
Fluorine	F	19	Sodium	Na	22.997
Gadolinium	Gd	157.3	Strotium	Sr	87.63
Gallium	Ga	69.72	Sulphur	S	32.06
Germanium	Ge	72.6	Tantalum	Ta	181.4
Gold	Au	197.2	Tellurium	Te	127.5
Helium	He	4	Terbium	Tb	159.2
Holmium	Ho	163.5	Thallium	Tl	232.12
Hydrogen	H	1.008	Thorium	Th	232.12
Indium	In	114.8	Thulium	Tm	169.4
Iodine	I	126.932	Tin	Sn	118.7
Iridium	Ir	193.1	Titanium	Ti	47.9
Iron	Fe	55.84	Tungsten	W	184
Krypton	Kr	83.7	Uranium	U	238.14
Lanthanum	La	138.9	Vanadium	V	50.95
Lead	Pb	207.22	Xenon	Xe	131.3
Lithium	Li	6.94	Ytterbium	Yb	173.5
Lutecium	Lu	175	Yttrium	Yt	88.92
Magnesium	Mg	24.32	Zinc	Zn	65.38
Manganese	Mn	54.93	Zirconium	Zr	91.22

The Formation and Occurrence of Mineral Veins

(Continued from page 2)

be repeated. In the case of arsenopyrite, repeated tests are sometimes necessary to find gold.

Experienced prospectors watch all float. Float means pieces of rock which are not "in place," or unattached. Talus slopes—debris fallen from a cliff—should be examined and mineralized float traced up the hill to its origin. Float carried by the glaciers and left in the glacial overburden, which is the soil mantle of much of the pre-Cambrian, should be traced back along the direction of the glacial movement. That direction is indicated by the glacial groovings in the solid rock.

NATIONAL TESTING LABORATORIES—ASSAYERS
223 JAMES STREET - WINNIPEG, MANITOBA

Table for Determination of Minerals by Field Tests

I. MINERALS OF METALLIC LUSTRE

A. Yellow or Yellowish Colour

1. Not Scratched with Knife

Brass-yellow; powder, greyish-black; crystallizes in cubes, octahedrons, etc.	**Pyrite**
Light-yellow or nearly white; powder, greyish black; inky, sour taste; forms wedge-shaped crystals.	**Marcasite**

2. Can be Scratched with Knife

Brass-yellow, often with many-coloured tarnish; powder, greenish-black or dark-green.	**Copper Pyrites**
Bronze-yellow, bronze-brown, or yellowish-grey; powder, black; magnetic.	**Pyrrhotite**
Pale yellow, powder, grey; brittle	**Calaverite**
Golden-yellow; does not powder, but spreads out.	**Gold**

B. Red or Reddish Colour

1. Hard to Scratch

Pale copper-red; powder, brownish-black; very heavy.	**Niccolite**
Copper-red, rosy shade; powder, reddish-brown; very heavy; hard.	**Breithaupite**
Brownish or greyish-red; powder, red; heavy.	**Hematite**

2. Easy to Scratch

Brown-red when fresh, tarnishes to purple, etc.; powder, greyish-black.	**Bornite**
Bright-red or brownish-red, lustre, near-metallic; powder, vermilion red, very heavy, soft	**Cinnabar**
Bright-red or reddish-black, lustre, near-metallic; powder, brownish-red, shining; heavy, soft	**Cuprite**
Reddish-black or black; lustre, near-metallic, powder, purple-red, heavy; soft.	**Pyrargyrite**
Vermilion-red, lustre, near-metallic; powder, vermilion-red	**Proustite**
Copper-red; does not powder, but spreads out	**Copper**

C. Grey Colour

1. Hard to Scratch

Steel-grey; powder, dull-red; sometimes micaceous, then seems soft.	**Hematite**
Tin-white to steel grey; powder, greyish-black. Yellow tinge; crystals grooved.	**Mispickle**
Tin-white to steel grey; powder, greyish-black. Blue tinge.	**Smaltite**

2. Easy to Scratch

(a) *Dark-Grey to Nearly Black*

Powder, grey-black; rather sectile[1]; cleavage, poor.	**Chalcocite**
Powder, grey-black; brittle; no cleavage.	**Tetrahedrite**
Powder, iron-black; slightly sectile; no cleavage.	**Petzite**
Perfectly sectile; shiny where cut or rubbed.	**Argentite**
Makes clean mark on white paper, grey when spread out by rubbing with finger; light.	**Graphite**

(b) *Lead-Grey*

Makes clean mark on white paper, greenish when spread out by rubbing with finger; heavy.	**Molybdenite**
Powder, lead-grey; rather sectile; cleavage, very perfect.	**Galena**
Powder, lead-grey; rather sectile; cleavage perfect, but often in streaks.	**Stibnite**
Powder, lead-grey; somewhat sectile, often yellowish or many-coloured tarnish, cleavage, perfect	**Bismuthinite**
Powder, light-grey, black tarnish, brittle	**Arsenic**
Powder, iron-black: somewhat sectile, cleavage, poor.	**Hessite**
Light-grey with yellowish tint: cubic cleavage.	**Altaite**

(c) *Steel-Grey*

Slightly sectile, soils paper, commonly in thin flexible crystals, cleavage, perfect.	**Tetradymite**
Sometimes yellowish, brittle; powder, steel-grey; cleavage, perfect.	**Sylvanite**
Powder, greyish-black, brittle, often needle-like crystals, cleavage, perfect	**Jamesonite**
Powder, greyish-black, brittle; cleavage, poor.	**Bournonite**

D. White Colour

1. Hard to Scratch

Silver-white to pale grey; powder, greyish-black; very heavy.

Yellow tinge; crystals grooved.	**Mispickel**
Blue tinge.	**Smaltite**

2. Easy to Scratch

Malleable; many have brown or black tarnish.	**Silver**
Sectile; rather hard	**Dyscrasite**
Sectile, softer; slightly reddish tint; very perfect cleavage.	**Bismuth**
Brittle; sometimes yellowish; powder, steel-grey; cleavage, perfect.	**Sylvanite**
Brittle, sometimes pale-yellow, powder, yellowish-grey or greenish-grey; no cleavage	**Calaverite**

1-Sectile means the opposite of brittle: cuts like lead or cheese, without cracking in crumbling.

E. Black Colour

1. HARD TO SCRATCH

(a) Strongly Magnetic

Powder, black.	**Magnetite**

(b) Slightly Magnetic or Non-Magnetic

Powder, red.	**Hematite**
Powder, brown-red, dark brown, or black; no cleavage; slightly magnetic.	**Ilmenite**
Powder, brown; no cleavage; seldom magnetic, and then very slightly.	**Chromite**
Powder, brownish, greyish, or white; imperfect cleavage; very heavy; very hard.	**Tinstone**
Powder, dark-brown, no cleavage, slightly magnetic; like magnetite.	**Franklinite**
Powder, brownish-black, shiny, lustre, near-metallic; no cleavage, non-magnetic.	**Psilmelane**
Powder, brownish-black, greyish or olive-green, a little shiny, lustre, near-metallic; no cleavage; non-magnetic, looks like black pitch; very heavy.	**Pitchblende**
Powder, nearly black; cleavage, very perfect, sometimes slightly magnetic; very heavy; colour usually brown-black, lustre, near-metallic.	**Wolframite**

2. EASY TO SCRATCH

(a) Makes Clean Mark on Paper

Grey mark; mineral is light.	**Graphite**
Bluish-grey mark, slightly green when rubbed; mineral is heavy.	**Molybdenite**

(b) Too Hard to Make Clean Marks on Paper

Powder, black; brittle; fibrous or granular.	**Pyrolusite**
Powder, brown; brittle; lustre, near-metallic; cleavage, very perfect.	**Zinc Blende**
Powder, dark lead-grey, perfectly sectile.	**Argentite**
Powder, black; very heavy.	**Coloradoite**
Powder, red; heavy.	**Pyrargyrite**

II. MINERALS OF NON-METALLIC LUSTRE

A. Powder, Distinctly Coloured

1. POWDER, BACK OR BROWN-BLACK

Coal-black; soft; light; very brittle.	**Coal**
Brown to dull black; earthly; like bog iron.	**Bog Manganese**
Powder, black, brown-red, or dark brown; colour, black; hard; no cleavage; slightly magnetic.	**Ilmenite**
Lustre, near-metallic, very hard, cleavage, perfect.	**Braunite**
Lustre, near-metallic, hard.	**Psilomelane**
Lustre, near-metallic; pitchy; no cleavage; very heavy.	**Pitchblende**
Like pitchblende, but harder; not so heavy.	**Euxenite**

2. Powder, Brown

Not scratched by knife; very heavy; colour, black or brown; cleavage, poor.	**Tinstone**
Hard to scratch; heavy; colour, black; no cleavage.	**Chromite**
Hard to scratch; colour, black; powder, brown-red, dark-brown, or black; no cleavage; slightly magnetic.	**Ilmenite**
Easier to scratch; colour, black or brown; lustre, resinous; cleavage, perfect.	**Zinc Blende**
Soft or hard; colour, brown; no cleavage.	**Limonite**
Harder to scratch, colour, black or brown, lustre, near-metallic; like zinc blende, but harder and heavier.	**Wolframite**
Not scratched or very hard to scratch, colour, reddish-brown or red, lustre, near-metallic; fairly heavy, cleavage, distinct	**Rutile**

3. Powder, Yellow

Colour, dull-brown, brownish-yellow, or yellow; powder, brownish-yellow; no cleavage.	**Limonite**
Colour, deep-red or orange-yellow; powder, orange-yellow; cleavage, perfect	**Zincite**
Colour, canary-yellow, powder, canary-yellow.	**Carnotite**

4. Powder, Red

Colour, brick-red; powder, red or reddish-brown; earthly.	**Hematite**
Colour, cochineal-red, powder, vermilion-red, somewhat sectile	**Cinnabar**
Colour, conchineal-red, powder, brownish-red, shiny, crystals or earthly.	**Cuprite**
Colour, vermilion-red; powder, same, transparent or nearly so.	**Proustite**

5. Powder, Green

Colour, green; fairly hard; rather heavy.	**Malachite**
Colour, light apple-green; soft; light.	**Garnierite**

6. Powder, Blue

Colour, azure-blue; fairly hard.	**Azurite**

B. Powder, White or Faintly Coloured

1. Hard to Scratch, or Not Scratched

(a) Cleavage, Non or Indistinct

Colour, white, amethystine, or smoky, etc.; lustre, glassy; light; crystals, hexagonal.	**Quartz**
Colour, black, brown, or green; lustre, glassy; light; crystals; triangular prisms, grooved.	**Tourmaline**

Colour, garnet-red, brown, or green; lustre, glassy; fairly heavy; crystals, roundish.	**Garnet**
Colour, black, brown, grey or white; lustre, adamantine; very heavy; crystals, tetragonal.	**Tinstone**
Colour, yellowish or brown; lustre, adamantine; heavy, crystals, tetragonal, harder than quartz	
Colour, green, blue, yellow, or white, lustre, glassy, light, crystals, hexagonal, harder than quartz	

(*b*) *Cleavage, Distinct*

(1) *Rather Heavy*

$H=10$, $G=3.5$, cleavage, very perfect, roundish crystals; faces curved.	**Diamond**
$H=9$; $G=4$; cleavage, good (parting) crystals, hexagonal.	**Corundum**
$H=8$; $G=3.5$; cleavage, very perfect; crystals, grooved; colour, yellow.	**Topaz**
$H=5$ to 5.5; $G=3.5$; cleavage, fair crystals, flat or wedge-like; colour, brown.	**Sphene**

(2) *Not so Heavy*

$H=6.5$; colour, yellowish-green or brownish-green; crystals mostly long.	**Epidote**
$H=6.5$; colour, olive-green; crystals roundish.	**Olivine**
$H=5.5$; cleavage pieces with angles of 56° and 124°.	**Hornblende**
$H=5.5$; cleavage pieces with angles nearly 90°	**Pyroxene**

(3) *Light*

Cleavage, perfect, angles 90° or nearly 90°; lustre, rather pearly.	**Feldspar**
Cleavage, fair, angles 90°, lustre, rather glassy, cleavage surface, fibrous-looking	**Scapolite**
Cleavage, only fair; colour, blue, etc.	**Sodalite**
Cleavage, good; colour, white.	**Nepheline**

2. Easier to Scratch

(*a*) *Light* (*$G=2.7$ to 3.5*)

(1) *Hard as Calcite or Harder*

$H=3$; cleavage, remarkably perfect, pieces rhombohedral; colour, white.	**Calcite**

H=3.5; cleavage, perfect, pieces rhombohedral; colour, white.	**Dolomite**
H=3.5; cleavage, perfect, pieces rhombohedral; colour, pink.	**Rhodochrosite**
H=4; cleavage, perfect, pieces, rhombohedral; sometimes like porcelain; colour, white.	**Magnesite**
H=4; cleavage, perfect, with some faces equilateral triangles; colour, white, green or violet-blue.	**Fluorspar**
H=4 5 to 5, cleavage, perfect; colour, white, sometimes with pale-blue or green tint	**Calamine**
H=5; crystals, hexagonal; cleavage, imperfect; colour, green or brown, etc.	**Apatite**
H=2.5 to 4; not crystalline; fracture, conchoidal or splintery.	**Serpentine**

(2) *Softer than Calcite*

H=2.5 to 4; not crystalline; fracture, conchoidal or splintery.	**Serpentine**
H=2.5; looks like ice, especially if wet.	**Cryolite**
H=2 to 3, but feels softer because of easy splitting; cleavage, very perfect, into thin, elastic leaves.	**Mica**
H=2; colour, white; glistening; cleavage, very perfect; not elastic.	**Gypsum**
H=1 to 2; colour, green, etc.; fine-grained or in scales like mica; not elastic.	**Chlorite**
H=1; colour, white, pale-green, or grey; soapy feel.	**Talc**
Soft, powdery; clayey smell when breathed on; plastic when wet.	**China Clay**
H=1 to 3; colour, white, yellow, brown, or red; clayey smell when breathed upon; usually oolitic, that is, with round grains like fish eggs.	**Bauxite**

(*b*) *Heavy* (*G= 3.7 to 6.5*)

H=3, G=6 3, cleavage, distinct; very brittle; colour, white, slightly tinted.	**Anglesite**
H=3, G=6 5, cleavage, distinct; very brittle; colour, white; lustre, brilliant, like diamond.	**Cerussite**
H=2.5 to 3.5; G=4.5; cleavage, perfect; sometimes in flat crystals grouped so as to show wedge-like edges; colour, white.	**Barite**
H=3 to 3.5; G=4; cleavage, perfect; often fibrous; colour, white, faintly blue.	**Celestite**
H=3 5, G=3 7; cleavage, perfect, colour, white.	**Strontianite**
H=3 5, G=4 3, cleavage, distinct, colour, white.	**Witherite**
H=3.5; G=3.8; cleavage, perfect; colour, white or grey, often rusty.	**Siderite**
H=4 5, G=6, cleavage, distinct, colour, white, light-brown, or yellow	**Scheelite**
H=5, G=5, in roundisn grains; colour, red or brown	**Monazite**
H=5; G=4 3; mostly in roundish masses, crusts, etc, like calamine	**Smithsonite**

ROCKS

Rocks are distinguished by a somewhat different set of observations from minerals, since they consist of one or more minerals in grains or crystals, or of rock fragments adhering together in large bodies. We may therefore observe: (1) What minerals they contain; this is known as *mineralogical composition.* (2) the coarseness of fineness of their grain, or *texture.* (3) The arrangement of the grains (a) in parallel directions, (b) in a granular mass without noticeable arrangement, or (c) in parallel bands; or a composition of fragments of rocks or minerals cemented together. These differences are known as the *internal structure* of the rocks.

Mineralogical Composition

The mineralogical composition of a rock may be easily determined by the eye if the texture or size of its crystals or grains is large enough. If not, it may be distinguished by the use of the hand lens; or, if still finer, by a compound microscope. For field purposes, the eye or hand lens is sufficient if the texture is at all coarse. There are only six mineral types that one needs to recognize in order to distinguish the granular rocks. These are quartz, feldspar, mica, hornblende, pyroxene, and olivine. These suffice for those that consist essentially of crystals grown together, and these rocks are usually formed by the cooling of a fused mass or in some cases by heating without fusion. In the sedimentary and schistose rocks, a few others are needed, such as calcite, chlorite, epidote, and kaolin.

Hardness or softness in rocks is, of course, due to the nature of the minerals present, and is often useful in determination.

Grain or Texture

Grain or texture is important both in the igneous and sedimentary rocks. In the crystalline rocks we may distinguish (a) very course texture, as in pegmatite; (b) coarse texture, in rocks composed of crystals, or grains large enough to be distinctly recognizable by the eye; (c) porphyritic texture, in rocks composed of a few large and easily recognized crystals (phenocrysts) distributed through a "groundmass" of finer texture; (d) fine texture, in rocks whose particles are too small to be recognized by the eye; (e) glassy texture, in those rocks which have been chilled from the liquid condition too rapidly to allow of the growth of crystals; such rocks have a glassy non-metallic lustre.

Internal Structure

By internal structure in rocks we mean the arrangement observable in the constituent particles of minerals or rocks of which the rock mass is composed. The more important kinds of structure are:

1. *Granular.*—This was referred to above, under texture. It applies to those rocks that consist of a mass of crystals that display no parallel arrangement but have grown together in such a way as to form a more or less structureless mass. Such rocks are often referred to as massive. They are usually igneous or metamorphic.

2. *Fragmental or Clastic.*—This refers to rocks which are composed of fragments of other rocks or minerals cemented together by

other mineral substances. They include two main classes: (a) those formed from fragments of other rocks disintegrated by erosion; (b) those produced by volcanic action.

3. *Bedded of Laminated Structure.*—This applies to sedimentary or classic volcanic rocks that have been deposited in water. Owing to interruptions in the deposition, the rocks are divided into layers or beds. These, if thin enough to be seen in a hand specimen, would be called *laminae*. If thicker, they are known as *strata*, and are only observable in the field.

4. *Flow Structure.*—Some igneous rocks show layers or streaks of different colors owing to their flowing movements while in the liquid condition.

5. *Fissile Structures*—Many rocks can be split in certain directions, but not in others, owing to the parallel arrangement of certain minerals in them, especially mica, hornblende, chlorite, and talc, which crystallize in this scales or fibres. This arrangement of thin plates or fibres in parallel position is due to the "flowage," that is enforced movement caused by pressure on the rock *after* hardening. The thin plates of mica, chlorite, or talc and the fibres of hornblende arrange themselves in the direction in which the rock is being stretched or elongated under pressure of "shearing." The principal kinds of fissility are: (a) *Slaty*, produced, in shaly rocks by the growth of small mica scales lying parallel in shale; (b) *Schistose*, when the shearing process has reduced a rock to mica or other platy or fibrous minerals arranged in parallel, generally with some quartz between the layers; (c) *Gneissic or Gneissoid*, where a certain amount of feldspar is present, in addition to the minerals that produce the fissility. The feldspar is present, in addition to the minerals that produce the fissility. The feldspar often forms separate bands between layers which are practically schist.

Arrangement of Rock Tables

In tables for the identification of rocks, the above properties are chiefly depended upon. In those of very fine texture, colour, lustre, hardness, odour, and fracture may also be of value.

TABLE FOR IDENTIFICATION OF ROCKS

A. Glassy in Texture

1. Glass lustre; conchoidal fracture.	**Obsidian**
2. Resinous or dull, pitchy lustre.	**Pitchstone**
3. Cellular; very light.	**Pumice**

B. Fine-Grained, or Dull and without Grain

(a) Scratched by Finger-Nail

1. Strong, clayey odour when breathed upon; greasy feel after long rubbing; does not fizz with acid.	**Clay** **Shale**
2. No clayey odour (marl may have clayey odour; no greasy feel; fizzes with acid.	**Chalk** **Marl**
3. Same as 2, but does not fizz with acid.	**Tripolite**
4. Harder; does not fizz with acid; good cleavage.	**Gypsum**
5. Soft; greasy feel; often in scales, like mica, but not elastic.	**Soapstone**

(b) NOT SCRATCHED WITH FINGER-NAIL BUT EASILY WITH KNIFE

1. Laminated; clayey odour; usually grey; no fizzing, or very little, with acid.	**Shale** **Slate**
2. No clayey odour, or very feeble; usually grey; powder, white; fizzes with acid.	**Limestone**
3. Same as 2, but fizzes only when acid is hot.	**Dolomite**
4. Usually greenish; powder, white; slightly soapy feel; lustre, often waxy; sometimes rather hard to scratch with knife; does not fizz with acid.	**Serpentine**

(c) NOT SCRATCHED WITH KNIFE; SCRATCHES CLASS

1. Colour, light, white in thin flakes; sometimes clayey odour.	**Rhyolite**
2. Very hard, scratches steel and feldspar; usually light in colour; conchoidal fracture.	**Flint** **Chert**
3. Not so hard as 1 and 2; colour, dark; heavy; sometimes with roundish holes or amygdules.	**Basalt**

C. Distinctly and Evenly Crystalline

(a) EASILY SCRATCHED WITH KNIFE

1. Fizzes with cold acid.	**Crystalline Limestone**
2. Fizzes only with hot acid.	**Dolomite**
3. Does not fizz with acid; brilliant cleavage surfaces.	**Gypsum**
4. Glassy lustre; cubic cleavage; salty taste.	**Rock Salt**

(b) NOT SCRATCHED, OR HARD TO SCRATCH WITH KNIFE

1. Usually light-coloued; composed of quartz and feldspar, often with mica or hornblende.	**Granite**
2. Same as 1, but no quartz.	**Syenite**
3. Dark-grey or black; composed of hornblende and feldspar.	**Diorite**
4. Dark-grey or black; heavy; composed of pyroxene and feldspar.	**Gabbro** **Diabase**
5. Dark-green to black; heavy; composed mostly of hornblende, pyroxene, or olivine.	**Amphibolite** **Pyroxenite** **Peridotite**
6. Composed of grain of quartz, more or less rounded.	**Sandstone** **Quartzite**
7. Same as 6, but with grains of feldspar, etc.	**Greywacke**

D. A Fine-Grained Mass with Some Large Crystals

1. Crystals of quartz and feldspar in a light-coloured mass.	**Quartz Porphyry** / **Granite Porphyry**
2. Crystals of feldspar in a light-coloured mass.	**Feldspar Porphyry** / **Syenite Porphyry**
3. Crystals of feldspar, hornblende, black mica, etc., in a dark-coloured mass; in dikes.	**Lamprophyre, etc.**

E. In Layers of Sheets, More or Less Distinct

1. Same composition as granite.	**Gneiss**
2. Mica and quartz.	**Mica Schist**
3. Green or black, mostly needle-like or bladed hornblende crystals.	**Hornblende Schist**
4. Fine-grained; usually grey; often clayey odour; splits into smooth, even slabs.	**Slate**
5. Greasy feel; marks cloth; easily scratched with finger-nail.	**Talc Schist**
6. Composed of sericite, a variety of mica, often with quartz or carbonate between the layers; usually light-coloured and glistening.	**Sericite Schist**
7. Harder than talc; smooth; green; powder, white or grey; shines like mica.	**Chlorite Schist**
8. Also Limestone, Shale, Slate—See B.	

F. Composed of Fragments of Rocks or Minerals

1. Rounded pebbles from the size of a pea to boulders.	**Conglomerate**
2. Angular pieces.	**Breccia**
3. Pieces of volcanic rock.	**Volcanic Tuff** / **Volcanic Breccia**
4. More or less rounded grains, mostly of quartz, from the size of a pea down.	**Sandstone**
5. Same as 4, but with feldspar grains.	**Arkose**
6. Grey colour; fine-grained; quartz, feldspar, and other minerals and rocks.	**Greywacke**

Systematic Classification of Rocks

Our Outline of Rocks is divided into two classifications: (1) *Igneous Rocks* and (2) *Sedimentary and Metalmorphic Rocks.*

1. *Igneous Rocks* are arranged according to (a) texture and structure (granular, porphyritic, glassy and gneissoid); and (b) mineral composition, if coarse-grained; or colour, hardness, lustre, etc., if the grain is too fine to distinguish the minerals.

1. *Sedimentary and Metamorphic Rocks* are arranged according to (a) structure (bedded, clastic, massive, slaty, schistose, or gneissic); and (b) mineral or other composition, hardness, odour, colour, etc.

Rock Elements and Rock Minerals

Of the 92 chemical elements, 10 compose over 98 per cent. of the outer part or "crust" of the globe, the only part with which we are familiar. There are reasons for thinking that the heavier of these ten also form most of the central part of the globe. The vast masses of material found on the earth's surface are composed of these elements and are known as rock. Rocks differ according to the proportions of the elements found in them. There are three distinct kinds of rock: (1) *Igneous*, formed by the cooling of melted masses formed below the surface; (2) *Sedimentary*, formed on the surface from other rocks; (3) *Metamorphic*, formed by changes in either of the others.

1. *Igneous Rocks* are composed of the following principal elements, 8 in number:

Oxygen (O)	
Silicon (Si)—*acid element*	
Aluminium (Al)	
Iron (Fe)	*Metallic elements*
Magnesium (Mg)	
Calcium (Ca)	
Sodium (Na)	
Potassium (K)	

The first of these is combined with each of the others to form eight (including two of iron *oxides*):

Silica (SiO_2), *Oxide of Silicon*
Aluminia (Al_2O_3), *Oxide of Aluminium*
Iron { *Ferric oxide* (Fe_2O_3)
     { *Ferrous oxide* (FeO)
Magnesia (MgO), *Magnesium Oxide*
Lime (CaO), *Calcium Oxide*
Soda (Na_2O), *Oxide of Sodium*
Potassia (K_2O), *Oxide of Potassium*

These oxides may exist in the *magma* or melted rock underground. In the cooled rock the eight oxides are found combined in six principal minerals:

QUARTZ, or Silica.

FELDSPAR—potassia, soda or lime, combined with aluminia and silica.

MICA—somewhat similar in composition.

HORNBLENDE } Composed of silica with the heavier metal oxides,
PYROXENE } especially lime, iron, and magnesia.

2. *Sedimentary Rocks* contain the same elements with the addition of carbon and hydrogen derived from the water and air of the earth's surface. The oxides of these are water (H_2O) and carbon dioxide (CO_2). The principal minerals found in these are *Quartz* (SiO_2), *Kaolin* ($Al_2O_3+2SiO_2+2H_2O$), and *Calcite* ($CaO+CO_2$).

3. *Metamorphic Rocks* also contain much hydrogen. The minerals peculiar to them are mica; hornblende, and chlorite, all of which contain water.

LICENSE AND PROXIES

NUMBER	NAME	ADDRESS

ASSAY RECORD

CLAIM REF. No.

Sample No.

Distance from ( ) to ( ) ft.
Width Sample Cut Vein w.
Comparative Grade Ore
Surface or Pit Sampled? Length V
Dip Strike Sack No.

Distance from ( ) to ( ) ft.
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